

# MEMS Microphones at Draper

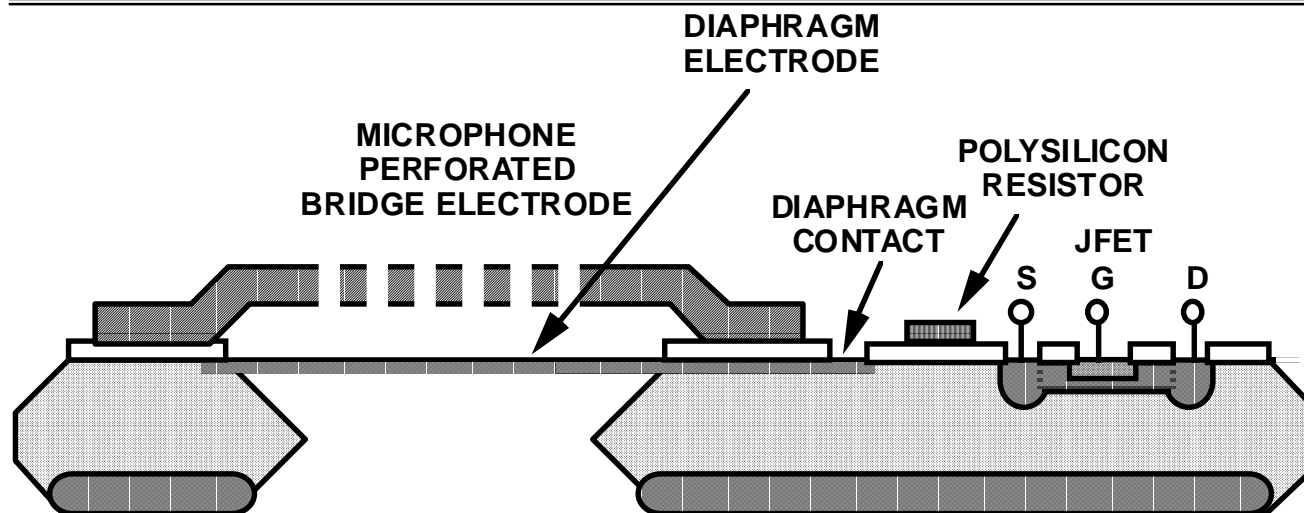
## **MEMS Air Acoustics Research The Charles Stark Draper Laboratory**

**J. Bernstein**

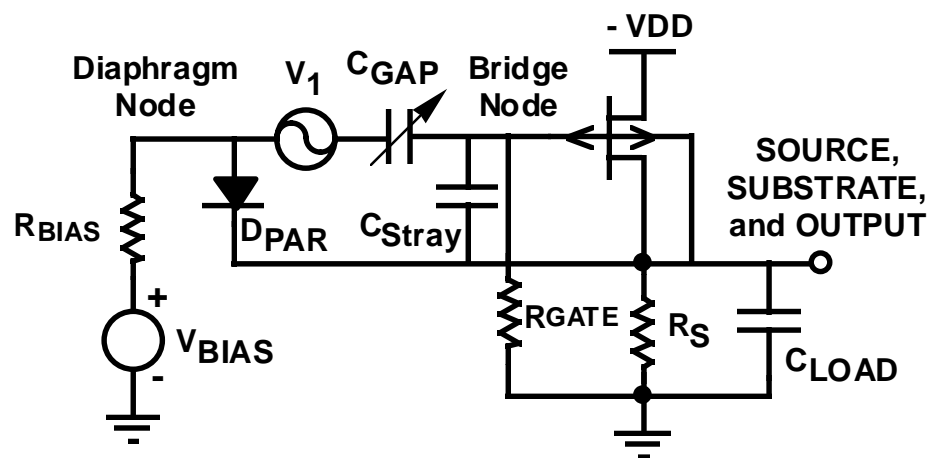
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# Condenser Microphone Cross-Section & Circuit Diagram

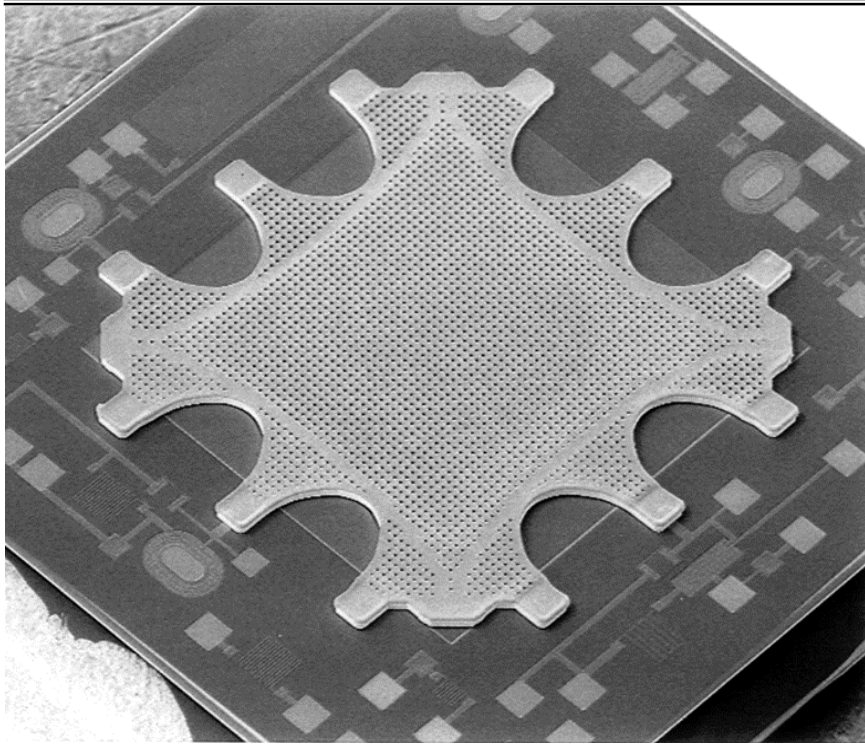


Cross-section of mike with on-chip JFET amplifier



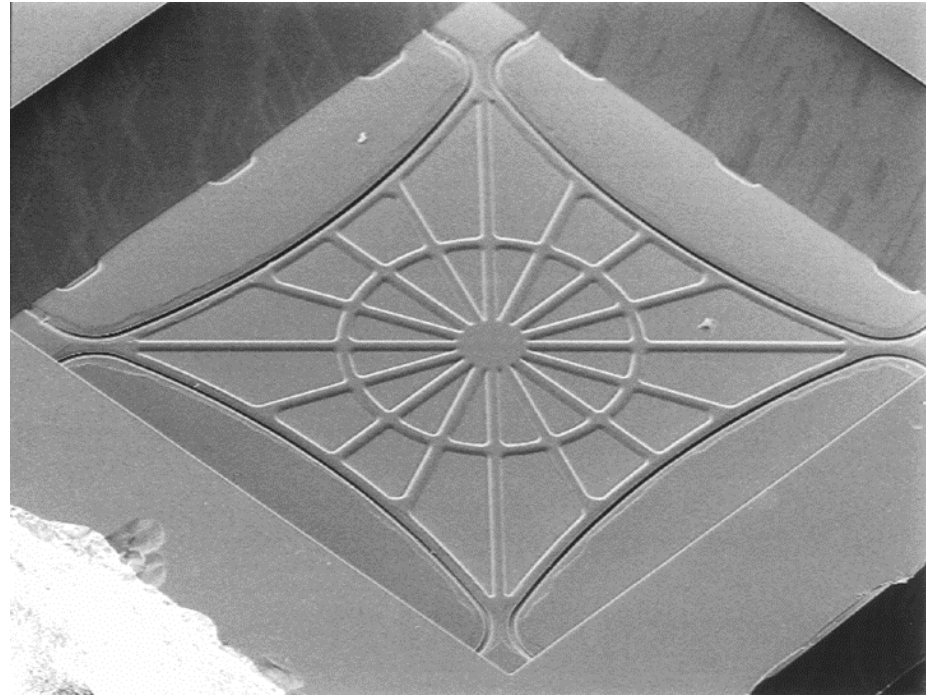
Circuit diagram with parasitics

# Micromachined Microphone



**Front view:**  
Perforated bridge electrode  
JFET buffer circuits

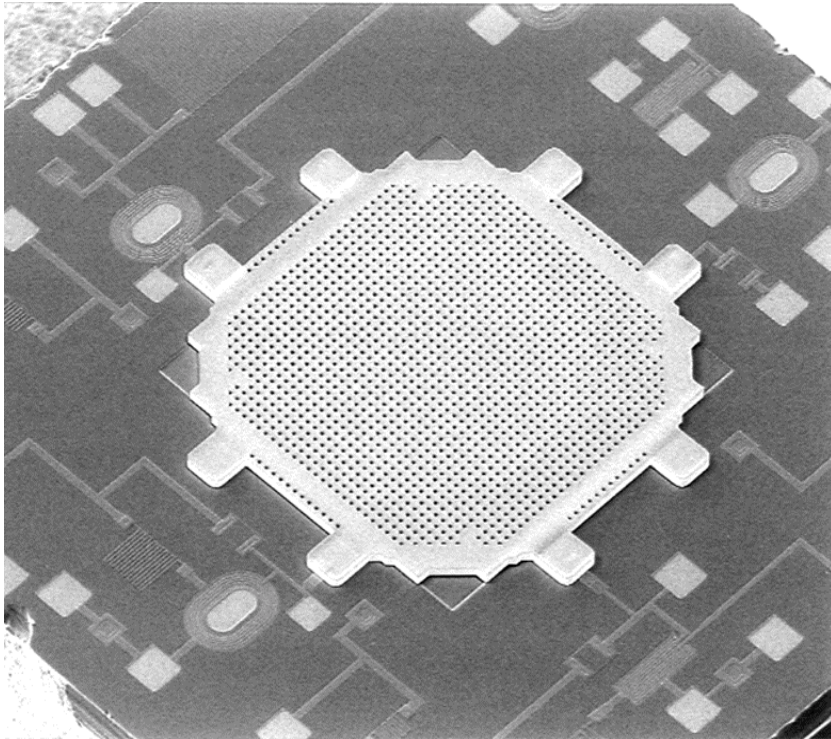
**Back view:**  
Reinforced silicon diaphragm  
Anisotropically etched through hole



## Micromachined Microphone With On-Chip Buffer Amplifier

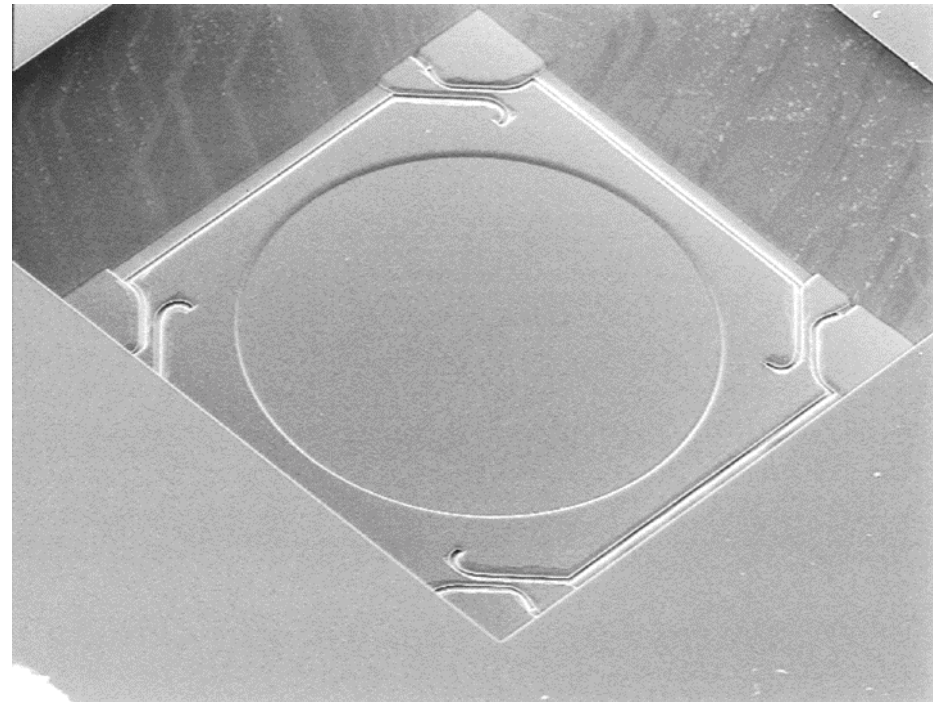
# Condenser Microphone 1mm Diaphragm

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**Top View:  
Bridge Electrode and Electronics**

**Bottom View of Diaphragm,  
Etch Pit and Springs**  
Center of diaphragm is 1 micron thick,  
Edges & springs are 6 microns thick

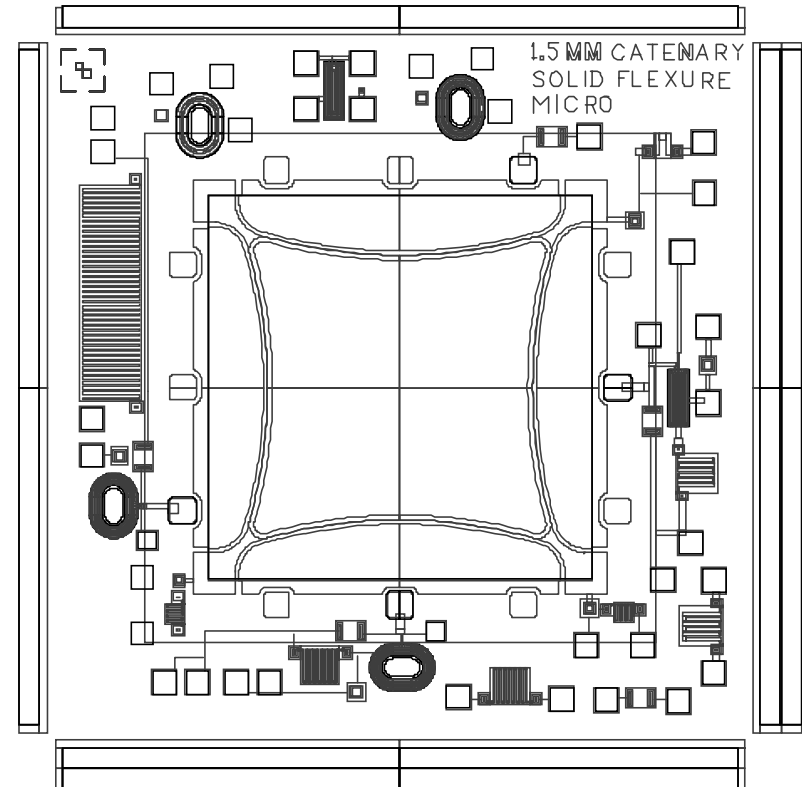
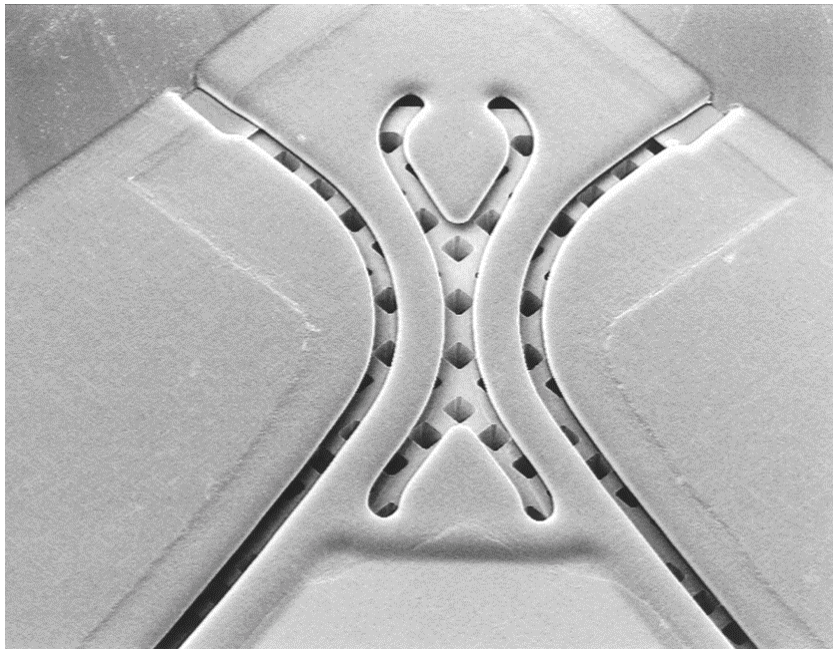


**Micromachined Microphone with 1mm Diaphragm**



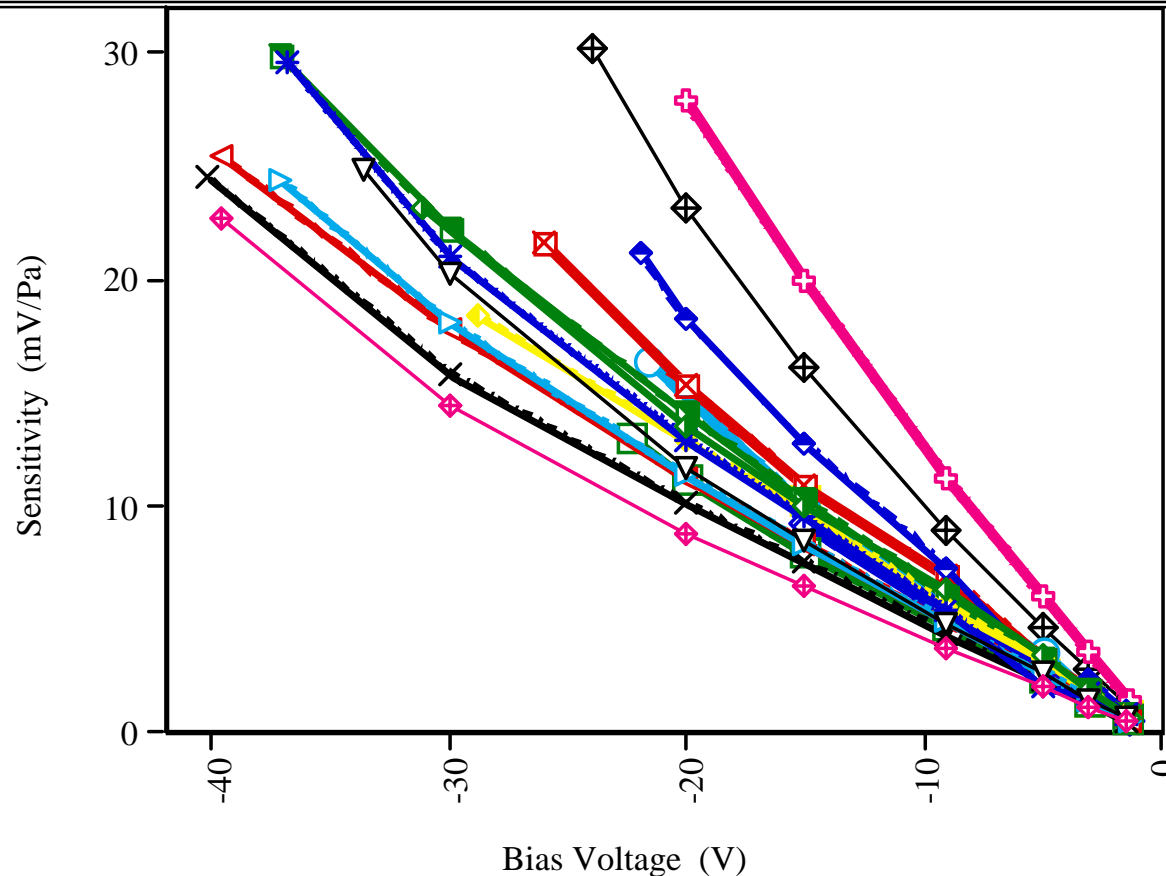
# Condenser Microphone Catenary Designs

- To reduce mass of diaphragm, a 1 micron Si layer was used, with a thin border of 6 micron silicon for strength.
- Catenary shape gives good compliance & flatness
- LIGA-like 20 micron thick gold plated electrode



Mask layout drawing

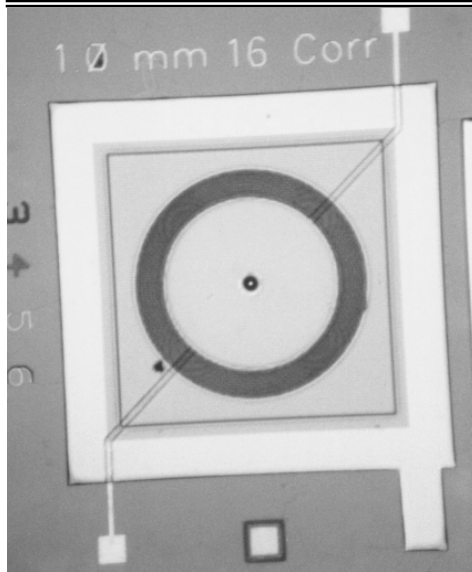
# Condenser Microphone Sensitivity vs. Bias Voltage



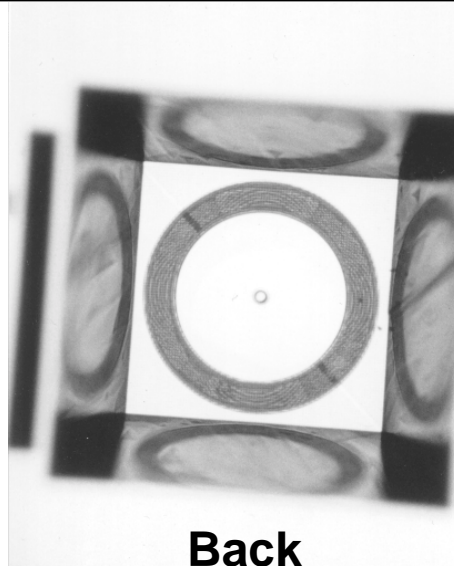
## Sensitivity vs. bias voltage for various microphone designs

- Sensitivity & bandwidth of these miniature MEMS microphones are better than commercially available hearing aid microphones
- Bandwidth of 20-30 kHz depending on design

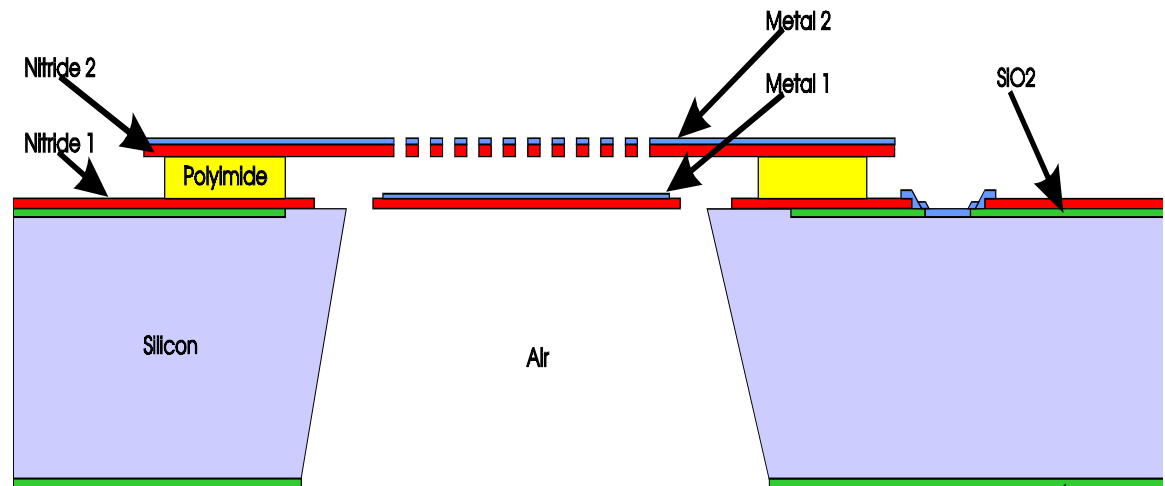
# Nitride Membrane Microphones



**Round diaphragms  
with corrugations  
(front)**



- Silicon nitride membrane microphones were developed for increased bandwidth
- Novel fabrication process
- Polyimide sacrificial layer
- Stress-control of  $\text{Si}_3\text{N}_4$  critical
- Work by B. Cunningham



**Nitride diaphragm microphone cross-section**



# Conclusions

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- **Draper has developed high sensitivity MEMS condenser microphones**
  - **On-chip JFET amplifiers to reduce stray capacitance**
  - **Single crystal silicon diaphragms**
  - **Electroplated perforated bridge electrodes**
  - **Si<sub>3</sub>N<sub>4</sub> membrane fabrication process also developed**
- **Custom designs for ultrasound or infrasound possible**
- **Arrays can be built as easily as one sensor**
- **Technology licensed to:**
  - NCT, National Semiconductor and Siemens (Munich)**

## References

- J.J. Bernstein and J. T. Borenstein, "A Micromachined Silicon Condenser Microphone With On-Chip Amplifier", Digest of the 1996 Solid State Sensor and Actuator Workshop, pp. 239-243, Hilton Head, S.C., June 2-6, 1996.
- B. Cunningham and J. Bernstein, "Wide Bandwidth Silicon Nitride Membrane Microphones", SPIE Micromachining and Microfabrication Process Technology III, Austin TX, September 29-30 1997.